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Evaluation of Spanish Universities: Efficiency, Technology and Productivity Change

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Introduction

In recent years demand for accountability and transparency has increased in most industrialized countries. The pressure on public budgets has led governments to control and pursue efficiency and productivity in the allocation and management of public sector resources (Bonaccorsi & Daraio, 2005). This public concern has forced government to take responsibility for evaluation and control of public funding institutions. Governments have started to develop evaluation systems and programs to control these institutions, systems that are proving beneficial for the design of policy to improve the effectiveness of funding institutions.

There is a wide range of public institutions involved. Education institutions are of interest because education, especially higher education, is one of the main sources of economic growth (Denison, 1962). Verry & Davies (1976, p.1.) comment that "Universities are major users of the nation's resources. Inefficiency in the university sector represents a real welfare loss as surely as does the misallocation of resources elsewhere in the economy.

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In this sense, at least, higher education is no different from any other industry." Thus, designing and making improvements in educational policy can lead to higher economic growth.

Numerous studies have looked in depth at the efficiency and productivity of universities. Measuring efficiency and productivity in public higher education institutions (HEI) provides an indirect evaluation of public funding management, informs policy making and improves university productivity and consequently public funding management (García-Valderrama, 1996).

Productivity in higher education has an obvious multidimensional character as it relates to both production and dissemination of knowledge through its various activities of teaching, research, and outreach activities (Dundar & Lewis, 1998). In this sense, measuring productivity in the higher education context is complicated. Changes in productivity growth can be calculated using the Malmquist productivity change index, which is a particularly attractive methodology (Johnes, 2005). It does not require knowledge of input or output prices, nor does it require any specific behavioral assumptions about the institutions under consideration, such as cost minimization or profit or revenue maximization (Coelli & Perelman 1999; O'Donnell & Coelli 2003; Uri 2003a, 2003b; Rodríguez-Álvarez *et al.,* 2004). The methodology has been applied in a number of service industry contexts, including healthcare (Maniadakis & Thanassoulis, 2000; Ventura, Gonzalez & Carcaba, 2004; Worthington, 2004) and financial services (Worthington, 1999; Mahlberg & Url, 2003; Sturm & Williams, 2004).

Some education studies also use the Malmquist index approach. Worthington & Lee (2005) examine productivity changes in the Australian university sector between 1998 and

2003; Flegg *et al.,* (2004) examine changes in productivity in the British university sector over the period 1980/81 to 1992/93. In both cases, the authors used the non-parametric technique in which the selection of inputs and outputs used to define the production function for modeling university behavior (teaching, research and technology transfer) is complicated. Indeed, there is no definitive method for selecting inputs and outputs (Tomkins & Green, 1988; Beasley, 1990, 1995; Johnes & Johnes, 1993, 1995; Glass, McKillop & Hyndman, 1995; Athanassopoulos & Shale, 1997; Worthington, 2001). Most indicators typify the ambiguity found in education performance measurements (e.g. excellent results may be due to high entry qualifications rather than effective teaching) and do not capture the interaction among the various inputs and outputs (Gomez, 2001; Joumady & Ris, 2005) and the limitations imposed by the selected output specification.

Studying output is problematic. In the case of *teaching***,** for example, one would prefer measures of the learning (concepts and competencies) that results from teaching, such as number of students enrolled (Hanke & Leopoldseder, 1998), full-time equivalent students enrolled, student credit hours (Sinuany-Stern *et al.*, 1994), number of degrees conferred (Arcelus & Coleman, 1995), number of PhD graduates. For instance, credit hours can differ significantly among programs for full-time students (e.g. science students involved in laboratory research versus humanities students) and these differences more likely reflect input differences than learning differences. Degrees awarded measures completions and a level of accomplishment or extent of learning, but does not take account of the education of those that attended courses but did not graduate, nor does it recognize differences in the lengths of degree programs (within or across universities), such as between three and four year undergraduate programs, details that full-time equivalent enrolment do capture. Cohn *et al.* (1989) maintain that numbers of students that have graduated represents an accumulated output of several years, depending on time length of degree; the efforts of non-graduated students is overlooked and there are no criteria measuring quality.

Research output is equally difficult to measure. The ideal would be an index that reflects the quality and impact of activities undertaken, and their products, but no such index exists. Publication counts are sometimes used as a measure of research output (Van de Panne, 1991; Sinuany-Stern *et al.,* 1994), although sometimes the data are difficult to obtain and are typically incomplete. For example, the publication count variable used by De Groot *et al.* (1991) in their study of the cost structure of US research universities did not include humanities publications. Useful outputs include published books, book chapters and refereed journal articles and conference proceedings, but again data are not always available. Sarafoglou & Haynes (1996) use number of articles and number of citations and their impact factor. Tomkins & Green (1988) use both publications counts and grants. Lacking reliable and easily obtainable output measures, many studies substitute research grant, which is an input, as a proxy for research output (Rhodes & Southwick, 1986; Ahn *et al.*, 1988; Tomkins & Green, 1988; Cohn *et al.*, 1989; Ahn & Seiford, 1993). Ahn *et al.* (1989) use a blend of this approach, taking state funds allocated to state HEI as the input and federal and private research funds as the output.

In addition, the promoting of the so-called third-mission activities at the universities might be seen as one of the major strategies adopted in recent years. A large debate is undergoing about the consequences of including among the institutional missions of universities, in addition to research and teaching, the so-called third mission. In this sense, the issue of third mission might be framed as a problem of complementarily vs substitution in output. The activities carried out by universities should be seen as a vector of outputs produced jointly, using the same vector of inputs. From this perspective, both positive and negative effects are plausible. In general, studies that examine single scientific areas find positive correlation between classical indicators of scientific activity and involvement into third mission activities, while studies that examine aggregate effects at university level more often find mixed results. Therefore, this evolution of the system has placed increasing emphasis on the relevance of assessing universities' performance.

Despite the wide variety of inputs — for example, faculty, support staff, student services, libraries, computers, equipment and supplies, maintenance, buildings, etc. — they can usually be defined relatively well in terms of amounts or expenditures. Traditionally, numbers of undergraduate or doctoral students have been used (Ahn & Seiford, 1993; Athanassopoulus & Shale, 1997; Hanke & Leopoldseder, 1998; García-Aracil, 2006) as both teaching and a research inputs, along with academic and non-academic staff measured in terms of full-time equivalents or numbers (Van de Panne, 1991), or staff costs (Ahn *et al.*, 1988; Hanke & Leopoldseder, 1998). In addition, total expenditure has been taken as an input (Ahn *et al.*, 1988), broken down into R&D expenditures (Ahn, 1987), capital expenses (Johnes, 2005), library expenses (Rodhes & Southwick 1986), computer services and structures (Ahn *et al.*, 1988, 1989, 1993), and/or space costs (Besset *et al.*, 1980). Variations in input quality are not so easily distinguished.

There is no consensus about some variables as inputs or outputs, for example, number of undergraduate students, research income, research grants, and measures used to assess technology transfer are difficult.

Thus, in the absence of specific, agreed measurements to evaluate HEI, in this paper we apply the Malmquist non-parametric approach to analyze productivity changes in Spanish public universities from 1994 to 2004. The variables we employ are: as inputs - total expenditure, numbers of academic staff and non-academic staff (a proxy for teaching and research); as outputs we use numbers of graduates (a proxy measure of education), publications (a proxy for research) and applied research (a proxy for knowledge transfer).

The paper is organized as follows. Section 2 presents some stylized facts concerning the higher education system in Spain and the descriptive data used in the analysis. Section 3 briefly describes the Malmquist methodology. Section 4 explains the results of the productivity analysis, and Section 5 offers some concluding remarks.

Description of the higher education system in Spain

Institutional setting

Spanish universities are among the oldest in the world. The University of Salamanca was founded in the early 13th century (1215). These early institutions were not much like current universities. They were small and focused on such fields as Law, Philosophy and Theology. The ruling monarch and the Church had an important role in the operation of these early institutions.

The 19th century was critical for Spanish universities. At the beginning of the 19th century, liberalism stemming from the French Revolution changed the structure of the State. Under the “Napoleonic” system of higher education adopted by Spain, universities became state agencies, totally regulated by state laws and norms, issued at national level (Mora & García-Aracil, 2005). Universities had no specific budgets, and expenditure was regulated by the state down to the smallest detail. Until very recently, academic programs were identical in all institutions. This strictly regulated, higher education system was also an elitist system (Mora, 2005). The monopoly of the state over higher education that originated in Spain was seen as a way of protecting universities against social forces, which opposed academic freedom and independence of knowledge. Unlike other countries where private ownership of the universities was the guarantee of freedom and independence from external powers, in Spain the state became the guarantor of freedom in terms of university teaching and administration.

In 1983 an important legal reform was enacted, the University Reform Act (*Ley de Reforma Universitaria*, LRU). The main changes introduced by the LRU were: (i) that universities became autonomous entities with the capacity to establish their own programs and, to some extent, their curricula; (ii) that there was a strong democratization of the internal structure of universities; and (iii) that responsibility for universities was transferred from the central government to the 17 autonomous regions of Spain. Regional governments oversaw the financial and organizational aspects of universities. However, the tradition of "national diplomas" and civil servant status for university staff was retained, and central government can still participate in the establishment of the general rules governing the curricula, accreditation of study programs, and definition of the duties and salaries of academic staff (which are the same in every public university).

At the dawn of the new millennium, Spanish universities were given a new context as a result of : (i) the new legal framework which was drawn up by central government towards the end of 2001 (*Ley de Ordenación Universitaria*, LOU); (ii) the agreement among all European governments to transform the structure of higher education in European countries (the Bologna Declaration); and (iii) the decrease in the numbers of students as a consequence of the dramatic drop in the birth-rate in Europe.

This last point warrants some further explanation. The Spanish higher education system experienced rapid growth in the last three decades when it became a mass higher education system catering for a high proportion of secondary school leavers. Currently, there are 1.5 million students enrolled, 13.9 per cent in private institutions (CCU, 2004). However, the number of students is decreasing due to the marked reduction in the numbers of young people at higher education age. This decline in student numbers is extremely important. There is no guarantee that there will be a demand for the available university places. Will institutions and staff that have until now always experience growth in the system, find it easy to adapt to a new era in which efficient use of available resources will become the main objective?

Descriptive data

The data used in the present study were collected during 2004 by the project *Advanced Quantitative Methods for the Evaluation of the Productivity of Public Sector Research* (AQUAMETH) within the framework of PRIME, a European Network of Excellence, which is supported by the European Commission's Sixth Framework Programme (2002-2006).

Data for the academic years 1994/95 to 2004/05 for public universities in Spain were collected from various government and institutional sources. In 2004, there were 48 public institutions in existence; this study considers 43 of them. Five universities, (Pablo Olavide University, Technical University of Cartagena, University Miguel Hernandez and University Rey Juan Carlos), which were recently created, are excluded because of lack of data for some of the years in the period under study and due to their different structures as National Open Universities (UNED).

The AQUAMETH data set includes information for each of the 43 public institutions, based on the accounting system and a broad classification of appropriations and expenditures; human resources data providing information about the academic and non-academic staff; enrolment data for undergraduate and graduate programs; institutional information on physical resources, and publications data, among others.

We identified variables related to inputs and outputs of interest for this study: total expenses, academic and non-academic staff, graduates, publications and data on applied research.

Total expenses are based on a broad classification that includes expenditure on academic staff, expenditure on non-academic staff, running expenses in relation to goods and services, financial expenditures, flow of funds, capital expenses, real investment, and other expenses (financial assets plus financial liabilities). The amounts are expressed in thousands of euros (CRUE, 1996, 1998, 2000, 2002, 2004, 2006).

Academic and non academic staff refers to the total staff of the university (regardless of their role). In Spain, the position of researcher does not exist as an independent category. The academic staff has both teaching and research duties, although there are no clear rules relating to the research duties for academic staff. Non-academic staff includes the technical and administrative staff (CCU, 1999; INE, 2004, 2006).

Data concerning graduates refer to the number of people that achieved degrees between 1st January and 31st December of each year, and correspond to the academic year that ends in that year (CCU, 2003, 2004, 2005).

Publications refer to the number of publications authored by the university, i.e. with at least one author from the university in question. Data are from the Web of Science which includes five databases; only three were exploited for this study - the Science Citation Index Expanded (SCI-E), Social Sciences Citation Index (SSCI), and the Arts and Humanities Citation Index (AHCI). One problem in this context is that year refers to the year that information was entered into the database and is not necessarily the same as the year that the article was published. Another problem is that the number of publications per public university was calculated through global counting. This means that if an article has several university addresses in its author line, it is counted for each university mentioned. Moreover, if an article is attributed to more than one scientific field, it is counted for each scientific field mentioned (Web of Science, 2005).

Data on applied research refers to the income from private contracts under article 83 in the LOU (Spanish Higher Education Law).

Table I presents a summary of descriptive statistics for inputs and outputs across the 43 universities by year. Sample mean, standard deviation, maximum, minimum, skewness and kurtosis are reported. As can be seen, in 2004 on average expenditure was 6,934,820 euros and the number of academic staff was 1,952 and non-academic staff 921, a ratio of one technical/administrative staff to two academic staff. Also, on average, Spanish universities had 3,614 graduates and produced 597 publications. Highlighting changes over the sample period, we can see that on average expenditure increased by 16.00 percent (from 5,976,530 euros in 1994 to 6,934,820 euros in 2004), academic staff numbers increased by 27.18 percent (from 1,535 to 1,952), non-academic staff increased by 23.97 percent (from 743 to 921), number of graduates increased by 16.31 percent (from 3,107 to 3,614), number of publications increased by 94.71 percent (from 306 in 1994 to 597 in 2004) and applied research was the output with the highest increase. Thus, it is observed that increases in outputs were more or less matched by an increase in inputs.

The distributional properties of the six variables are shown in Table I. They appear non-normal. Given that the sampling distribution of skewness is normal with mean 0 and standard deviation of $\sqrt{T/6}$ where T is the sample size, many of the series are significantly skewed. Since these are also positive they signify a greater likelihood of observations lying above the mean than below. Across each of the years in the sample period, the most highly skewed variables are graduates and publications. The kurtosis or degree of excess across some variables is also large, thereby indicating leptokurtic distributions with extreme observations. Given that the sampling distribution of kurtosis is normal with mean 0 and standard deviation of $\sqrt{T/24}$ where T is the sample size, then many of the estimations are statistically significant at any conventional level. Graduates and publications are again highly leptokurtic.

[Table I about here]

Methodology

The methodology used to study productivity growth in Spanish public universities, from 1994 to 2004, is the nonparametric Malmquist index. This productivity growth method is superior to other indexes, such as the Törnqvist index or the Fisher Ideal index, because Malmquist index is based on quantity data only, and makes no assumptions regarding university behavior (Grifell-Tatjé & Lovell 1996).

Several different decompositions of the Malmquist index have been proposed in the literature. Fare *et al.* (1994) assume constant returns to scale (CRS) technology; Ray &

Desli (1997) use another decomposition that does not require CRS assumptions. Simar & Wilson (1998) and Zofío & Lovell (1998) extend Ray & Desli's (1997) decomposition by further decomposing the technical change component into a "pure" technical change plus a residual measure of the scale change in the technology. This residual measure evaluates the separation between CRS and variable returns to scale (VRS) technologies.

In this study, we initially assume CRS and calculate total productivity change, decomposed into technological (or technical) change and technical efficiency change, which includes "pure" efficiency change and scale efficiency change.

Furthermore, in applying the Malmquist methodology to study productivity, it is necessary to construct a nonparametric envelopment frontier over the data points, such that all observed points lie on or below the production frontier. There are two analytic options: input orientation, which reduces the inputs without dropping the output levels, and output orientation, which raises outputs without increasing the inputs. In terms of education, universities are given a fixed quantity of resources (e.g., state financial resources, academic and non-academic loads) and asked to produce as much output as possible. Thus, we assume an output orientation.

The output-based Malmquist productivity change index *(M)* specified by Färe *et al.* (1994) can be formulated as:

$$M_o^{t+1,t}(y_t, x_t, y_{t+1}, x_{t+1}) = \left[\frac{D_o^t(y_{t+1}, x_{t+1})}{D_o^t(y_t, x_t)} * \frac{D_o^{t+1}(y_{t+1}, x_{t+1})}{D_0^{t+1}(y_t, x_t)} \right]^{1/2}$$

where the subscript O indicates an output-orientation, M is the productivity of the most recent production point (x_{t+1}, y_{t+1}) (using period $t + 1$ technology) relative to the earlier production point (x_t, y_t) (using period t technology), D_0 is the output distance function which is the reciprocal of Farrell's (1957) technical efficiency measures. The output distance function is defined on the output set *P(x),* as:

$$D_o(x,y)\text{:min } \{\theta\text{: } (y/\theta) \in P(x)\}$$

where θ is the corresponding level of efficiency. The output distance function seeks the largest proportional increase in the observed output vector *y* provided that the expanded vector (y/θ) is still an element of the original output set (Grosskopf *et al.*, 1995). If the university is fully efficient such that it is at the frontier, $D_o(x,y)= \theta =1$, whereas $D_o(x,y)= \theta <1$ indicates that the institution is inefficient.

An equivalent way of writing the Malmquist index is:

$$M_o^{t+1,t}(y_t, x_{t,} y_{t+1,} x_{t+1}) = \frac{D_o^{t+1}(y_{t+1}, x_{t+1})}{D_0^t(y_t, x_t)} \left[\frac{D_o^t(y_{t+1}, x_{t+1})}{D_o^{t+1}(y_{t+1,} x_{t+1})} * \frac{D_o^t(y_t, x_t)}{D_0^{t+1}(y_t, x_t)} \right]^{1/2}$$

or *M=E*P* where *M* is the product of a relative efficiency change *E* under CRS, which measures the degree of catching up to the best-practice frontier level for each observation between time period *t* and time period *t + 1* (term outside the square bracket) and a measure of technical progress *P* (the two ratios in the square bracket) as measured by shifts in the frontier of technology (or innovation) measured at period *t + 1* and period *t* (averaged geometrically). We can obtain measures of overall technical efficiency *(E)* and "pure" technical efficiency *(PT)* by applying the same data CRS assumption (without convexity constraint) and VRS (with convexity constraint). Dividing overall technical efficiency *(E)* by "pure" technical efficiency change *(PT)* yields a measure of scale efficiency change *(S).*

Recalling that *M* indicates the degree of productivity change, if $M>1$ then productivity gains occur, whilst if $M<1$ productivity losses occur. Regarding changes in efficiency, technical efficiency increases (decreases) if, and only if, *E* is greater (less) than 1. An interpretation of the technological change index is that technical progress (regress) has occurred if P is greater (less) than 1.

To calculate the indices, it is necessary to solve several linear programs to maximize the function with the premises. Assume there are N universities and that each university consumes varying amounts of K different inputs to produce M outputs. The *ith* university is therefore represented by the vectors $x_i y_i$ and the $(K\times N)$ input matrix X and the $(M\times N)$ output matrix Y represent the data for all universities in the sample. The first two linear programs are where the technology and the observation to be evaluated are from the same period, and the solution value is less than or equal to unity. The second two linear programs occur where the reference technology is constructed from data in one period, whereas the observation to be evaluated is from another period. The following linear programs are used:

$$\left[D_0^{t+1}(y_{t+1}, x_{t+1})\right]^{-1} = \max_{\theta,\lambda} \theta$$
$$\text{s.t.} \quad \theta y_{i,t+1} + Y_{t+1}\lambda \geq 0,$$
$$x_{i,t+1} - X_{t+1}\lambda \geq 0$$
$$\lambda \geq 0$$

$$\left[D_0^{t}(y_{t}, x_{t})\right]^{-1} = \max_{\theta,\lambda} \theta$$
$$\text{s.t.} \quad \theta y_{i,t} + Y_{t}\lambda \geq 0,$$
$$x_{i,t} - X_{t}\lambda \geq 0$$
$$\lambda \geq 0$$

$$\left[D_0^{t+1}(y_{t}, x_{t})\right]^{-1} = \max_{\theta,\lambda} \theta$$
$$\text{s.t.} \quad \theta y_{i,t} + Y_{t+1}\lambda \geq 0,$$
$$x_{i,t} - X_{t+1}\lambda \geq 0$$
$$\lambda \geq 0$$

$$\left[D_0^{t}(y_{t+1}, x_{t+1})\right]^{-1} = \max_{\theta,\lambda} \theta$$
$$\text{s.t.} \quad \theta y_{i,t+1} + Y_{t}\lambda \geq 0,$$
$$x_{i,t+1} - X_{t}\lambda \geq 0$$
$$\lambda \geq 0$$

This approach can be extended by decomposing the CRS technical efficiency change into scale efficiency and “pure” technical efficiency components. Further details on the interpretation of these indices may be found in Charnes *et al.* (1993), Lovell (2003), Worthington & Lee (2005).

Results

To evaluate Spanish public universities, first, we analyze a “general model” taking as inputs total expenses, number of academic and non-academic staff, and as outputs graduates, publications and applied research. Then, in order to understand the sources of the productivity changes three additional specifications of university productivity are examined. The first focuses on “teaching-only” productivity, the second on “research-only” productivity and the third “industry-only” productivity. Variable definitions in both instances are identical to the “general model”, but the “teaching-only” specification does not include the output publications and applied research, the “research-only” specification excludes the output graduates and applied research and the “industry-only” specification does not include graduates and publications. Ideally, the remaining variables should be split along the lines of research-related and teaching-related, but this was not possible.

The Malmquist index and its decompositions for each of the four models are presented in Table II by year and by university. Three primary issues are addressed in the computation of the Malmquist indices of productivity growth over the sample period. The first is the measurement of productivity change over the period (see column *M* in Table II). The second is to decompose changes in productivity into what are generally referred to as a “catching-up” effect (technical efficiency change) (see column *E* in Table II) and a “frontier shift” effect (technological change) (see column *P* in Table II). The third is that the “catching-up” effect is further decomposed to identify the main source of improvement, either through enhancements in “pure” technical efficiency (see column *PT* in Table II) or increases in scale efficiency (see column *S* in Table II). It should be remarked that these indices (and any resulting percentage changes) are relative, that is, a university may be more or less efficient, or more or less productive, but only in reference to the other 42 universities.

Table II shows that the “general-model” showed an annual mean increase in total factor productivity *(M)* of 4.6 percent for the period 1994 to 2004 across the university sector. Given that productivity change is the sum of technical efficiency and technological change, the major cause of productivity improvements can be ascertained by comparing the values for efficiency change and technological change. That is, the productivity gains described could be the result of efficiency gains, or technological improvements, or both. In our case, the overall improvement in productivity over the period is composed of an average efficiency increase (movement towards the frontier) of 0.6 percent, and average technological progress (upward shift of the frontier) of 4.0 percent annually. Technical efficiency can be further decomposed into “pure” technical efficiency (0.5) and scale efficiency (0.1). Clearly, across all Spanish public universities the sustained improvement in productivity over the period 1994-2004 is the result of a sustained expansion in the frontier relating inputs to outputs, rather than any improvements in efficiency.

[Table II about here]

In the analysis by years, the highest mean productivity improvement was in academic year 1996/1997 with 10.5 percent, which was composed of 7.9 percent improvement in efficiency (the highest in the period analyzed) and 2.4 percent of technological gain. In turn, most of the technical efficiency gain was due to improvements in “pure” technical efficiency (5.6 percent) and scale efficiency (2.2 percent). By way of comparison, the high level of technological improvement was spread across the sector in the academic year 2001/2002 (26.2 percent), but with a fall in efficiency (-16.4 percent).

Looking at the results by universities, the University #17 had a mean productivity improvement of 12.2 percent (first-ranked) which was composed of 5.8 percent improvement in efficiency (moving towards the efficiency frontier) and 6.0 percent technological gain (movement in the frontier). Technical efficiency comprised an improvement in “pure” technical efficiency (5.9 percent) and a reduction in scale efficiency (-0.1 percent). The University #39 was ranked second in terms of productivity (12.0 percent) comprising a 2.3 percent technological gain and a 9.5 percent improvement in efficiency, which in turn comprised 10.8 percent “pure” efficiency change and -1.2 percent scale efficiency. The University #15 was ranked third, with a productivity gain of 10.2 percent – 6.1 percent to technological progress and 3.9 percent to improvements in efficiency.

At the other end of the scale are universities with a low level of total factor productivity over the period. For example, productivity for the University #11 fell on average by 4.7 percent, for the University #23 by 2.0 percent, for the University #25 by 1.0 percent and for the University #38 by 0.4 percent. In all these cases, the decline in productivity was the result of inefficiency (negative result in efficiency change column), rather a contraction in their best-practice frontier (negative result in technological change column).

Focusing on the “teaching-model”, Table II shows that there was an annual mean increase in total factor productivity *(M)* of 3.8 percent for the period 1994 to 2004, which was composed of an improvement in technological change (4.0 percent) and a fall in technical efficiency change (-0.2 percent). It could be said that the improvement in teaching only productivity in Spanish universities has been sustained by the expansion in the frontier rather than by improvements in efficiency.

In the analysis by year, the highest mean for teaching only productivity improvement occurred in the academic year 1996/1997 with 9.8 percent, which was composed of 12.8 percent improvement in efficiency (the highest in the period analyzed) and -2.6 percent of technological loss. In contrast, the highest technological improvement was in the academic year 2001/2002 (35.1 percent), but this was offset by a decrease in teaching efficiency (-21.7 percent).

In the analysis by university, the first ranked university was the University #31 with a teaching only productivity of 12.0 percent which was composed of 9.6 percent improvement in efficiency and 2.2 percent technological gain. Moreover, this is one of the few universities were efficiency improved more than technological change. Technical efficiency was composed of improvement in pure technical efficiency (10.9 percent) with a fall in efficiency (-1.2 percent). The University #14 was ranked second in terms of teaching only productivity (10.4 percent) comprising a 5.7 percent technological gain and a 4.4 percent improvement in efficiency, which in turn was due to 4.2 percent "pure" efficiency change and 0.2 percent scale efficiency change. The University #16 was ranked third, with a productivity gain of 10.4 percent attributed 5.7 percent to technological progress and 4.4 percent to improvements in efficiency: 4.2 percent due to "pure" efficiency change and 0.2 percent due to scale efficiency.

The lowest teaching only productivity factor over the period was for the University #19 (-7.3 percent) due to the decrease in efficiency (-12.2 percent) caused mainly by the decreases in "pure" efficiency change (-11.2 percent) and scale efficiency (-1.1 percent). The Universities #6, #3 and #34 showed a reduction in teaching only productivity by 3.6, 2.7 and 2.4 percent, respectively, mainly due to decreased efficiency.

With regard to the "research-model", Table II shows that the annual mean increase in research only productivity was 9.5 percent for the period 1994 to 2004, which was composed of average efficiency increase of 5.7 percent, and average technological progress of 3.6 percent annually. The increment for technical efficiency can be decomposed into "pure" technical efficiency (4.8 percent) and scale efficiency (0.9 percent). It seems that Spanish universities' improvements in research only productivity are sustained by both expansions in the frontier and movement towards the efficiency frontier.

In the analysis by years, the highest mean research only productivity was in the academic year 1997/1998 with 17.7 percent, which was composed of 0.7 percent improvement in efficiency and 17.0 percent in technological gain. The lowest increase in research only productivity was in the academic year 1999/2000 with a 2.0 percent.

Looking at the results for universities, the best-ranked performers were the Universities #27 (31.8 percent), #20 (31.7 percent), #5 (31.5 percent) and #6 (30.4 percent), while the worst-ranked performers were the Universities #11 (-0.9 percent) and #35 (-0.3 percent).

With respect to the "industry-model", we can observe that the annual productivity growth was largely attributable to technological progress rather than efficiency improvements.

Conclusions

During the last two decades, the Spanish higher education system has seen many changes with a variety of causes the most important of which are political reforms and demographic factors. A University Act was passed in 1983 and again in 2001 and 2007 transforming the legislation applying to universities. In addition, the European Higher Education Area was created. These factors (among others) created a framework requiring a reorganization of the system by the various actors involved and a change in the goals of universities with the most significant being enhancement of the productivity of higher education.

Number of students increased (and, as a consequence, also the amount of faculties and institutions) up to 1998, when a decrease began in line with demographic trends. This new situation has triggered new conflicts. Both those involved in governance of universities and academic staff has become accustomed to a situation where growth was continuous and academic posts were plentiful. However, the situation is changing and new academic positions are not justifiable, requiring changes to staff policies, and abandonment of the general rule of assignment of academic staff almost matching the number of lectures delivered.

In this paper, we have examined the productivity of Spanish public universities from 1994 to 2004, applying the Malmquist Productivity Index to illustrate the contribution of efficiency and technological change to productivity change over the period. Four different specifications were used to assess Spanish public universities: the "general", the "teaching-only", the "research-only" and "industry-only" models. The inputs included in the analysis were total expenses, academic and non-academic staff and the outputs were graduates, publications and applied research.

The results indicate that annual productivity growth was largely attributable to technological progress rather than efficiency improvements. Gains in scale efficiency appear to have played only a minor role in productivity gains. The fact that technical efficiency contributes little suggests that most universities are operating near the best-practice frontier.

The separate analyses of teaching-only, research-only and industry-only productivity suggest that most productivity growth was associated with improvements in research rather than teaching and knowledge transfer. In turn, the increase in teaching productivity is mainly sourced from technological gains and little efficiency improvement, whereas the research gains are mostly associated with the removal of inefficiency rather than technological improvements. The interpretation of these results should be made with some caution, bearing in mind that there is an overlap in teaching and research related inputs. It is clear that much of the overall productivity improvement in universities over this period is associated with gains in research productivity. Of this, most can be accounted for by universities catching up to the frontier through pure technical efficiency improvements rather than to the frontier expanding over time. On the other hand, improvements in teaching productivity have been more modest and largely linked to technological improvements, but this was offset by a decrease in teaching efficiency. Giving the increased efficiency, further gains will have to rely on technical innovations. This will be a continuing challenge for the higher education sector. Further research is needed to analyze the trade-off between teaching, research and knowledge transfer missions.

References

AHN, T. (1987) *Efficiency and related issues in higher education: a Data Envelopment Analysis approach,* Graduate School of Business, Texas University.

AHN, T., ARNOLD, V., CHARNES A. & COOPER, W.W. (1989) DEA and ratio efficiency analysis for public institutions of higher learning in Texas, *Research in Governmental and Non-profit Accounting 5*, pp. 165-185.

AHN, T., CHARNES, A. & COOPER, W.W. (1988) Using DEA to measure the efficiency of non-for-profit organizations: A critical evaluation-comment, *Managerial and Decision Economics 9,* pp. 251-253.

AHN, T. & SEIFORD, L.W. (1993) Sensitivity of DEA to models and variable sets in a hypothesis test setting: The efficiency of university operations, *Creative and Innovative Approaches to the Science of Management,* Ijiri (ed.), Westport, CT: Quorum Book, pp. 191-208.

ARCELUS, F.J. & COLEMAN, D.R. (1995) *An efficiency review of university departments*, Faculty of Administration, University of New Brunswick, mimeographed.

ATHANASSOPOULOS, A.D. & SHALE, E. (1997) Assessing the comparative efficiency of higher education institutions in the UK by means of data envelopment analysis, *Education Economics 5*, pp. 117-134.

BEASLEY, J.E. (1990) Comparing university departments, *Omega 18*, pp. 171-183.

BEASLEY, J.E. (1995) Determining teaching and research efficiencies, *Journal of the Operational Research Society 46*, pp. 441-452.

BESSENT, A.M. & BESSENT, E.W. (1980) Determining the comparative efficiency of schools through Data Envelopment Analysis, *Educational Administration Quarterly 16*(2), pp. 57-75.

BONACCORSI, A. & DARAIO, C. (2005) Exploring size and agglomeration effects on public research productivity, *Scientometrics 63*(1), pp. 87-120.

CCU (1999) *Profesorado de las Universidades Públicas en Estadística Universitaria*, *2002-2003*, Consejo de Coordinación Universitaria, Madrid, Spain.

CCU (2003) *Estadística Universitaria*, *1994-2001*, Consejo de Coordinación Universitaria Madrid, Spain.

CCU (2004) *Estadística Universitaria*, *2002-2003,* Consejo de Coordinación Universitaria, Madrid, Spain.

CCU (2005) *Estadística Universitaria*, *2003-2004,* Consejo de Coordinación Universitaria, Madrid, Spain.

CHARNES, A., COOPER, W.W., LEWIN, A.Y. & SEIFORD, L.M. (1993) *Data envelopment analysis: Theory, methodology and applications,* Norwell, Mass: Kluwer Academic Publishers.

COELLI, T. & PERELMAN, S. (1999) A comparison of parametric and non-parametric distance functions: With application to European railways, *European Journal of Operational Research 117*(2), pp. 326-339.

COHN, E.R.S. & SANTOS, M.C. (1989) Institutions of higher education as multiproduct firms: Economies of scale and scope, *Review of Economics and Statistics 71*, pp. 284-290.

CRUE (1996) *La Univerisdad Española en Cifras, 1994, Información Académica, Productiva y Financiera de las Universidades Públicas Españolas*, Conferencia de Rectores de las Universidades Españolas, Madrid, Spain.

CRUE (1998) *La Univerisdad Española en Cifras, 1996, Información Académica, Productiva y Financiera de las Universidades Públicas Españolas*, Conferencia de Rectores de las Universidades Españolas, Madrid, Spain.

CRUE (2000) *La Univerisdad Española en Cifras, 1998, Información Académica, Productiva y Financiera de las Universidades Públicas Españolas*, Conferencia de Rectores de las Universidades Españolas, Madrid, Spain.

CRUE (2002) *La Univerisdad Española en Cifras, 2000, Información Académica, Productiva y Financiera de las Universidades Públicas Españolas*, Conferencia de Rectores de las Universidades Españolas, Madrid, Spain.

CRUE (2004) *La Univerisdad Española en Cifras, 2002, Información Académica, Productiva y Financiera de las Universidades Públicas Españolas*, Conferencia de Rectores de las Universidades Españolas, Madrid, Spain.

CRUE (2006) *La Univerisdad Española en Cifras, 2004, Información Académica, Productiva y Financiera de las Universidades Públicas Españolas*, Conferencia de Rectores de las Universidades Españolas, Madrid, Spain.

DE GROOT, H., MCMAHON, W.W. & VOLKWEIN, J.F. (1991) The cost structure of American research universities, *The Review of Economics and Statistics 73*(3), pp. 424-431.

DENISON, E. F. (1962) *The sources of economic growth in the United States and the alternatives before us,* United States, Committee for Economic Development Study.

DUNDAR, H. & LEWIS, D.R. (1998) Determinants of research productivity in higher education, *Research in Higher Education 39*(6), pp. 607-631.

FARE, R., GROSSKOPF, S., NORRIS, M. & ZHANG, Z. (1994) Productivity growth, technical progress, and efficiency change in industrialized countries, *American Economic Review 84*, pp. 66-83.

FARRELL, M.J. (1957) The measurement of productivity efficiency, *Journal of the Royal Statistical Society*, *Series A (General) 120*, pp. 253-289.

FLEGG, A., ALLEN, D.O., FIELD, K. & THURLOW, T.W. (2004) Measuring the efficiency of British universities: A multi-period data envelopment analysis, *Education Economics 12*(3), pp. 231-249.

GARCÍA-ARACIL, A. (2006) Overview of regional differences in the Spanish higher education system, in Bonaccorsi., A. & Cinzia, D. (eds.) *Universities and Strategic Knowledge Creation*, Edward Elgar Publishing Ltd, UK.

GARCÍA-VALDERRAMA, T. (1996) La medida y el control de la eficiencia en las entidades públicas a través del análisis envolvente de datos, *Presupuesto y gasto público 20*.

GLASS, J.C., MCKILLOP, D.G. & HYNDMAN, N.S. (1995) The achievement of scale efficiency in UK universities: a multiple-input multiple-output analysis, *Education Economics 3*, pp. 249-263.

GÓMEZ SANCHO, J. M. (2001) *La evaluación de la eficiencia en las universidades públicas españolas,* Universitat de Lleida, Spain.

GRIFELL-TATJÉ, E. & LOVELL, C.A.K. (1996) A generalized Malmquist productivity index, *Top 7*(1), pp. 81-101.

GROSSKOPF, S., MARGARITIS, D. & VALDMANIS, V. (1995) Estimating output substitutability of hospital services: A distance function approach, *European Journal of Operational Research 80*(3), pp. 575-587.

HANKE, M. & LEOPOLDSEDER, T. (1998) Comparing the efficiency of Austrian universities. A data envelopment analysis application, *Tertiary Education and Management 4*(3), pp. 191-197.

INE, NATIONAL INSTITUTE OF STATISTICS (2004) *Estadística de la Enseñanza Superior en España,* Madrid, Spain.

INE, NATIONAL INSTITUTE OF STATISTICS (2006) *Estadística de la Enseñanza Superior en España,* Madrid, Spain.

JOHNES, J. (2005) Efficiency and productivity change in the English higher educational sector from 1996/97 to 2002/03, http://www.lums.lancs.ac.uk/publications

JOHNES, G. & JOHNES, J. (1993) Measuring the research performance of UK economics departments: an application of data envelopment analysis, *Oxford Economic Papers 45,* pp. 322-347.

JOHNES, J. & JOHNES, G. (1995) Research funding and performance in U.K. university departments of economics: A frontier analysis, *Economics of Education Review 14*(3), pp. 301-314.

JOUMADY, O. & RIS, C. (2005) *Determining the relative efficiency of European Higher Education institutions using DEA,* University of New Caledonia, ROA Maastricht University.

LOVELL, C.A.K. (2003) The decomposition of Malmquist productivity indexes, *Journal of Productivity Analysis 20*, pp. 437-458.

MAHLBERG, B. & URL, T. (2003) Effects of the single market on the Austrian insurance industry, *Empirical Economics 28*(4), pp. 813-838.

MANIADAKIS, N. & THANASSOULIS, E. (2000) Assessing productivity changes in UK hospitals reflecting technology and input prices, *Applied Economics 32*, pp. 1575-1589.

MORA, J. G. (2005). *Higher education in Spain,* Unpublished Document presented in Turku workshop, 10-13 February, Finland.

MORA, J. G. & GARCÍA-ARACIL, A. (2005) Dall'Università al Mercato del Lavoro. Modelli di Analisi e Risultati. Il Caso della Spagna, in Almalaurea, in *La Transizione dall'università al lavoro in Europa e in Italia*, Bologna, Italy.

O'DONNELL, C. & COELLI, T. A. (2003) Bayesian approach to imposing curvature on distance functions, *Centre for Efficiency and Productivity Analysis Working Paper 03/2003*, School of Economics University of Queensland.

RAY, S C. & DESLI, E. (1997) Productivity growth, technical progress and efficiency change in industrialized countries: Comment, *American Economic Review 87*(5), pp. 1033-1039.

RHODES, E. L. & SOUTHWICK, L. (1986) *Determinants of efficiency in public and private universities,* Department of Economics, University of South Carolina.

RODRIGUEZ-ALVAREZ, A., FERNANDEZ-BLANCO, V. & LOVELL, C.A.K. (2004) Allocative inefficiency and its costs: the case of Spanish public hospitals, *International Journal of Production Economics 92*, pp. 99-111.

SARAFOGLOU, N. & HAYNES, K.E. (1996) University productivity in Sweden: A demonstration and explanatory analysis for economics and business programs, *Annals of Regional Science 30*, pp. 285-304.

SIMAR, L. & WILSON, P. (1998) Productivity growth in industrialized countries, *Discussion paper 9810*, Institut de Statistique, Université Catholique de Louvain, Belgium.

SINUANY-STERN, Z., MEHREZ, A. & BARBOY, A. (1994) Academic departments efficiency via DEA, *Computers Operations Research 21*(5), pp. 543-556.

STURM, J.E. & WILLIAMS, B. (2004) Foreign bank entry, deregulation and bank efficiency: Lessons from the Australian experience, *Journal of Banking and Finance 28*(7), pp. 1775-1799.

TOMKINS, C. & GREEN, R. (1988) An experimental in the use of DEA for evaluating the efficiency of UK university departments of Accounting, *Financial,Accountability and Management 4*(2), pp. 147-164.

URI, N.D. (2003a) Technical efficiency in telecommunication in the United States and the impact of incentive regulation, *Applied Mathematical Modeling 27*, pp. 53-67.

URI, N.D. (2003b) The adoption of incentive regulation and its effect on technical efficiency in telecommunications in the United States, *International Journal of Production Economics 86*, pp. 21-34.

VAN DE PANNE, C. (1991) *Performance evaluation of academic units,* Department of Economics, University of Calgary mimeographed.

VENTURA, J., GONZALEZ, E. & CARCABA, A. (2004), Efficiency and program-contract bargaining in Spanish public hospitals, *Annuals of Public and Cooperative Economics 75*(4), pp. 549-573.

VERRY, D.W. & DAVIES, B. (1976) *University Costs and Outputs*, Elsevier, Amsterdam.

WEB OF SCIENCE (2005) http://wos02.isiknowledge.com

WORTHINGTON, A.C. (1999) Malmquist indices of productivity change in Australian financial services, *Journal of International Financial Markets, Institutions and Money 9*(3), pp. 303-320.

WORTHINGTON, A.C. (2001) An empirical survey of frontier efficiency measurement techniques in education, *Education Economics 9*, pp. 245-268.

WORTHINGTON, A.C. (2004) Frontier efficiency measurement in health care: A review of empirical techniques and selected applications, *Medical Care Research and Review 61*(2), pp. 135-170.

WORTHINGTON, A.C. & LEE, B.L. (2005) Efficiency, technology and productivity change in Australian universities 1998-2003, *Working Paper 05/01*, University of Wollongong School of Accounting and finance.

ZOFÍO, J.L. & LOVELL, C.A.K. (1998) Yet another Malmquist productivity index decomposition. *Mimeo*, Departamento de Economía, Universidad Autónoma de Madrid.

Tables

Table I. Descriptive statistics for inputs and outputs across the 43 universities by year.

Year	Statistics	Expenses *('000€)*	Academic Staff *(number)*	Non-acad. Staff *(number)*	Graduates *(number)*	Publications *(number)*	Applied Research *('000€)*
1994	Mean	5,976.53	1,535.09	743.04	3,107.44	306.98	1,262.04
	Std.deviation	4,368.68	1,095.32	579.81	3,215.15	334.10	1,087.94
	Minimum	939.18	285.00	135.19	459.00	7.00	137.55
	Maximum	20,324.80	5,491.00	2,899.96	18,534.00	1,562.00	6,152.23
	Skewness	1.24	1.42	1.68	2.97	1.87	1.10
	Kurtosis	1.53	2.62	3.50	12.06	4.06	1.04
1995	Mean	6,770.77	1,784.12	771.49	3,441.49	360.74	1,462.45
	Std.deviation	4,919.13	1,344.59	588.12	3,583.68	396.98	1,260.71
	Minimum	932.93	367.00	136.00	573.00	18.00	159.40
	Maximum	22,654.28	7,352.00	2,984.00	21,367.00	1,873.00	7,129.18
	Skewness	1.19	1.99	1.71	3.27	1.99	0.91
	Kurtosis	1.40	5.83	3.71	14.53	4.56	0.83
1996	Mean	7,010.14	1,846.44	797.53	3,782.40	392.91	1,271.17
	Std.deviation	4,846.34	1,293.54	596.60	3,692.18	420.93	1,095.81
	Minimum	1,289.54	385.00	183.00	765.00	18.00	138.55
	Maximum	22,608.63	6,727.00	3,017.00	22,050.00	1,995.00	6,196.73
	Skewness	1.33	1.76	1.84	3.16	2.00	1.62
	Kurtosis	1.50	3.61	3.59	13.78	4.57	1.15
1997	Mean	6,396.16	1,902.23	841.07	4,090.30	418.74	1,636.64
	Std.deviation	4,271.65	1,310.39	630.01	3,746.72	436.53	1,410.87
	Minimum	1,352.85	411.00	198.00	846.00	39.00	178.39
	Maximum	20,250.61	7,112.00	3,203.00	21,902.00	2,239.00	7,978.36
	Skewness	1.20	1.78	1.64	2.94	2.23	1.52
	Kurtosis	1.36	4.63	3.48	11.67	6.44	1.21
1998	Mean	6,303.56	1,805.98	838.86	4,216.02	461.88	1,908.62
	Std.deviation	4,121.59	1,182.53	605.00	3,470.14	457.58	1,645.33
	Minimum	1,484.87	362.00	201.00	856.00	51.00	208.03
	Maximum	19,632.44	6,019.00	3,282.00	20,559.00	2,218.00	9,304.21
	Skewness	1.16	1.33	1.79	2.72	1.94	0.92
	Kurtosis	1.41	2.48	5.36	10.90	4.23	0.70
1999	Mean	6,038.64	1,869.56	883.98	4,271.81	492.44	2,225.80
	Std.deviation	3,789.43	1,205.73	623.27	3,371.48	462.92	1,918.76
	Minimum	1,507.77	379.00	205.00	996.00	65.00	242.61

	Maximum	18,383.07	6,019.00	3,303.00	19,240.00	2,312.00	10,850.40
	Skewness	1.16	1.33	1.79	2.33	1.94	1.08
	Kurtosis	1.28	2.03	4.35	8.17	4.67	0.81
2000	Mean	5,310.00	1,944.40	927.40	4,218.67	491.35	2,579.25
	Std.deviation	3,229.42	1,206.75	652.86	3,160.19	462.29	2,223.45
	Minimum	1,391.79	379.00	202.00	832.00	52.00	281.13
	Maximum	15,836.95	6,035.00	3,504.00	16,870.00	2,346.00	12,573.40
	Skewness	1.13	1.25	1.82	1.88	2.07	1.25
	Kurtosis	1.20	1.85	4.60	4.95	5.24	0.94
2001	Mean	5,368.72	1,902.35	969.35	4,206.53	526.12	2,988.7
	Std.deviation	3,270.08	1,197.24	664.40	3,037.45	473.23	2,576.42
	Minimum	1,306.64	415.00	140.00	977.00	74.00	325.76
	Maximum	16,241.30	6,021.00	3,509.00	16,095.00	2,482.00	14,569.41
	Skewness	1.21	1.39	1.66	1.80	2.15	1.44
	Kurtosis	1.45	2.23	3.82	4.45	6.03	1.09
2002	Mean	5,488.72	1,898.37	959.19	4,538.00	546.14	3,706.46
	Std.deviation	3,357.24	1,181.64	651.24	3,209.23	467.33	3,524.55
	Minimum	1,247.61	419.00	217.00	1,083.00	86.00	402.39
	Maximum	16,805.48	6,021.00	3,509.00	15,770.00	2,518.00	13,475.95
	Skewness	1.26	1.38	1.81	1.35	2.15	1.42
	Kurtosis	1.66	2.38	4.47	2.11	6.44	1.12
2003	Mean	6,169.54	1,910.28	908.28	4,178.40	595.86	4,424.22
	Std.deviation	3,773.67	1,193.03	646.04	3,172.51	442.25	4,035.72
	Minimum	1,895.49	305	235	630	41	379.21
	Maximum	17,389.26	5,961	3,540	13,826	2,650	15,362.36
	Skewness	1.27	1.50	2.03	1.30	1.97	1.35
	Kurtosis	1.68	2.50	5.55	1.08	4.82	0.90
2004	Mean	6,934.82	1,952.28	921.19	3,614.35	597.72	5,141.98
	Std.deviation	2,773.93	1,192.84	663.56	2,644.52	440.35	4,966.53
	Minimum	1,370.91	477	236	267	71	94.31
	Maximum	17,993.32	5,896	3,563	13,924	2,238	19,625.78
	Skewness	1.25	1.48	1.96	1.76	1.99	1.50
	Kurtosis	1.61	2.21	4.94	4.32	4.88	1.62
94-04	Mean Variation	16.00%	27.18%	23.97%	16.31%	94.71%	278.91%

Table II. Malmquist index by year and by Spanish public universities

	General Model					Teaching Model					Research Model					Industry Model				
Year/index	E	P	PT	S	M	E	P	PT	S	M	E	P	PT	S	M	E	P	PT	S	M
94-95	4.6	-1.2	4.2	0.4	3.4	4.2	-1.4	4.8	-0.6	2.8	8.4	3.0	7.7	0.6	11.6	0.1	4.5	0.0	0.1	4.6
95-96	2.7	4.3	4.3	-1.5	7.1	0.7	6.0	2.5	-1.7	6.7	-1.1	8.5	4.9	-5.7	7.2	7.3	2.6	5.1	2.1	10.1
96-97	7.9	2.4	5.6	2.2	10.5	12.8	-2.6	7.2	5.2	9.8	19.1	-5.2	13.8	4.7	12.8	-2.8	-2.4	-2.8	0.0	-5.1
97-98	0.8	7.5	-4.0	5.0	8.4	-2.8	10.1	-5.8	3.2	7.0	0.7	17.0	0.6	0.1	17.7	-1.0	27.2	-4.7	3.9	25.9
98-99	1.0	-0.3	1.6	-0.6	0.7	2.8	-3.5	2.7	0.1	-0.8	10.0	0.2	6.7	3.1	10.2	-1.6	3.8	-2.1	0.5	2.2
99-00	-1.2	2.1	0.2	-1.4	0.9	0.6	-0.5	2.0	-1.4	0.0	-4.2	6.5	-5.8	1.7	2.0	-1.9	4.8	-1.1	-0.8	2.9
00-01	7.6	-6.0	3.2	4.3	1.1	5.8	-5.9	3.4	2.3	-0.4	13.8	-3.5	7.2	6.2	9.9	3.3	1.9	4.6	-1.3	5.2
01-02	-16.4	26.2	-10.2	-6.9	5.5	-21.7	35.1	-15.2	-7.7	5.7	1.5	3.8	4.2	-2.7	5.3	-11.8	6.9	-8.4	-3.8	-5.7
02-03	-21.3	33.6	-14.4	-8.0	5.1	-11.8	6.5	-6.0	-6.2	-6.0	13.9	-4.0	8.9	4.7	9.3	-15.3	33.3	-9.3	-6.7	12.9
04-05	-5.8	4.1	-6.1	0.3	-2.0	37.3	-38.1	21.7	12.8	-15.0	6.8	-9.6	8.0	-1.1	-3.4	-16.3	23.5	-7.7	-9.4	3.3
All years	0.6	4.0	0.5	0.1	4.6	-0.2	4.0	0.0	-0.1	3.8	5.7	3.6	4.8	0.9	9.5	-0.8	2.6	-0.3	-0.5	1.8

	General Model					Teaching Model					Research Model					Industry Model				
University/index	E	P	PT	S	M	E	P	PT	S	M	E	P	PT	S	M	E	P	PT	S	M
1	1.8	7.0	0.3	1.5	8.9	5.0	4.4	6.1	-1.0	9.5	4.0	5.9	2.2	1.9	10.2	-20.8	26.8	-15.3	-6.5	0.5
2	-0.9	5.2	-1.6	0.7	4.2	-4.6	4.8	-4.8	0.2	0.0	5.4	5.5	6.0	-0.6	11.2	-10.4	25.1	0.3	-10.6	12.1
3	1.5	3.5	1.3	0.2	5.0	-7.2	4.8	-7.5	0.4	-2.7	-0.8	2.6	-0.3	-0.5	1.8	-11.6	20.9	-2.2	-9.6	7.0
4	-1.9	4.8	-1.1	-0.8	2.9	2.2	6.1	1.1	1.1	8.4	1.1	3.8	-0.6	1.8	5.0	-15.5	24.2	-16.5	1.1	4.9
5	3.7	2.6	2.7	1.0	6.4	2.3	3.5	2.2	0.1	5.8	27.3	3.3	26.3	0.8	31.5	-13.8	20.3	-1.5	-12.5	3.7
6	4.6	3.4	3.4	1.1	8.1	-7.1	3.8	-2.7	-4.5	-3.6	24.0	5.2	23.1	0.7	30.4	-7.6	22.1	5.5	-12.4	12.9
7	-1.6	3.8	-2.1	0.5	2.2	-1.8	4.2	-2.5	0.8	2.3	1.4	2.5	1.3	0.1	3.9	-4.4	27.6	-2.1	-2.4	21.9
8	2.0	5.2	4.6	-2.5	7.3	-1.8	4.7	-2.0	0.2	2.9	4.2	4.0	1.4	2.8	8.4	-30.0	27.6	-30.8	1.2	-10.7
9	-1.5	4.2	-1.5	0.0	2.6	2.6	3.6	0.8	1.7	6.2	2.4	3.9	2.1	0.3	6.3	-6.7	26.8	-6.5	-0.2	18.3
10	3.0	4.7	3.0	0.0	7.9	-0.9	4.9	-1.4	0.5	4.0	5.0	2.1	5.2	-0.2	7.3	-14.2	18.2	-11.9	-2.6	1.4
11	-9.2	4.9	-8.0	-1.3	-4.7	-5.1	4.4	0.0	-5.1	-0.9	-5.4	4.8	-8.3	3.2	-0.9	-2.3	19.2	13.6	-14.0	16.4
12	0.7	5.6	0.6	0.1	6.4	1.5	4.4	2.0	-0.5	6.0	2.4	4.6	2.7	-0.3	7.1	-24.6	18.0	-20.0	-5.7	-11.0
13	3.4	4.3	3.7	-0.3	7.8	2.1	3.5	2.1	0.1	5.7	7.4	3.0	8.3	-0.8	10.6	-21.4	24.7	-15.4	-7.1	-2.0
14	1.7	3.8	2.6	-0.9	5.6	4.4	5.7	4.2	0.2	10.4	1.9	2.5	3.5	-1.5	4.5	1.7	23.5	13.7	-10.6	25.5
15	3.9	6.1	3.7	0.2	10.2	-2.9	3.9	0.0	-2.9	0.9	1.7	4.8	0.8	0.9	6.6	-18.2	25.4	-18.9	0.8	2.5
16	0.0	3.4	0.0	0.0	3.4	3.5	6.4	1.9	1.6	10.1	1.9	3.7	0.0	1.9	5.6	-10.6	19.7	-15.9	6.3	7.0
17	5.8	6.0	5.9	-0.1	12.2	-2.1	3.3	-0.2	-1.9	1.1	16.6	5.7	17.2	-0.5	23.2	-16.8	27.3	-12.9	-4.5	5.8
18	-2.2	3.4	0.0	-2.2	1.2	3.7	2.6	2.7	1.0	6.4	8.0	4.1	13.6	-4.9	12.4	-23.4	11.8	-15.1	-9.8	-14.4
19	4.3	2.9	4.2	0.0	7.3	-12.2	5.6	-11.2	-1.1	-7.3	7.9	2.5	7.8	0.2	10.7	-4.2	14.8	-4.7	0.6	10.0
20	7.3	2.6	5.1	2.1	10.1	2.1	4.4	0.8	1.3	6.6	26.8	3.9	22.6	3.4	31.7	-13.2	20.2	-1.0	-12.4	4.3
21	2.0	3.3	1.8	0.1	5.4	0.1	4.6	-1.4	1.5	4.7	7.1	3.1	6.7	0.3	4.0	4.5	18.3	15.8	-9.8	23.6
22	-0.9	4.9	-1.4	0.5	4.0	1.4	3.7	1.3	0.1	5.2	5.1	3.9	4.0	1.1	9.2	9.1	22.2	13.4	-3.8	33.3

23	-5.8	4.1	-6.1	0.3	-2.0	-0.7	2.4	-1.8	1.1	1.7	-1.8	2.5	-2.2	0.4	0.6	-17.4	26.9	-14.8	-3.1	4.8
24	0.4	4.4	-2.0	2.4	4.8	0.1	4.5	0.0	0.1	4.6	3.0	3.6	-1.2	4.2	6.8	25.0	16.1	38.3	-9.6	45.1
25	-3.0	2.1	-3.0	0.0	-1.0	3.4	4.4	3.6	-0.3	7.9	1.7	2.1	1.3	0.4	3.8	-14.1	18.7	-15.6	1.8	2.0
26	-1.7	3.5	-1.1	-0.5	1.7	-1.8	3.2	-2.6	0.8	1.4	1.4	3.3	0.4	1.0	4.8	-11.8	20.4	-15.5	4.4	6.2
27	-1.8	4.2	-2.5	0.8	2.3	-2.7	3.2	-2.8	0.1	0.3	28.0	3.0	21.1	5.7	31.8	-6.8	22.5	13.3	-17.7	14.2
28	-0.7	2.7	-1.5	0.8	2.0	2.3	4.8	2.2	0.1	7.2	0.5	2.1	-0.1	0.6	2.6	5.5	26.6	15.6	-8.7	33.5
29	3.9	5.7	3.5	0.4	9.9	2.8	3.3	3.2	-0.4	6.2	1.9	3.2	2.2	-0.3	5.2	-13.8	24.5	-11.4	-2.7	7.4
30	-0.9	4.6	-1.1	0.1	3.6	4.3	3.0	2.1	2.2	7.5	3.7	3.9	4.3	-0.6	7.7	5.4	25.3	10.0	-4.2	32.1
31	2.6	6.2	1.1	1.5	9.0	9.6	2.2	10.9	-1.2	12.0	1.3	4.9	1.6	-0.2	6.3	0.1	27.6	8.3	-7.5	27.7
32	1.6	3.8	1.5	0.1	5.4	-1.2	3.1	-2.5	1.3	1.9	9.8	2.5	9.3	0.5	12.6	-54.3	26.4	-50.2	-8.2	-42.2
33	-0.3	2.0	-0.6	0.4	1.8	-1.5	2.4	-1.1	-0.4	0.9	3.7	2.5	3.4	0.3	6.3	-13.9	18.2	-12.4	-1.7	1.8
34	3.8	4.6	3.3	0.5	8.6	-5.0	2.7	-4.9	0.0	-2.4	11.9	3.4	10.1	1.6	15.6	-29.8	15.9	-21.4	-10.7	-18.6
35	-4.3	4.1	-5.2	0.9	-0.4	2.1	2.8	0.0	2.1	4.9	-3.4	3.2	-4.2	0.7	-0.3	-14.9	18.9	-8.2	-7.3	1.2
36	0.0	4.5	0.0	0.0	4.5	-0.5	3.8	-0.3	-0.1	3.3	0.0	4.3	0.0	0.0	4.3	6.6	14.3	10.6	-3.6	21.8
37	3.5	3.2	1.5	1.9	6.9	5.1	4.5	4.7	0.3	9.8	10.1	3.3	2.9	7.1	13.8	10.1	14.5	23.0	-10.5	26.1
38	-4.8	4.5	0.0	-4.8	-0.5	-3.6	2.4	-4.2	0.7	-1.2	-1.9	4.2	-4.5	2.8	2.3	-15.2	27.3	-16.7	1.8	8.0
39	9.5	2.3	10.8	-1.2	12.0	1.8	4.7	5.3	-3.3	6.6	9.2	3.0	7.0	2.0	12.4	1.8	27.9	0.0	1.8	30.2
40	-2.1	3.2	-2.1	0.1	1.1	-1.3	4.7	-1.4	0.1	3.4	0.9	2.5	1.1	-0.2	3.4	-12.1	24.8	-8.7	-3.7	9.8
41	0.3	2.7	-0.9	1.2	3.0	-2.2	3.8	-0.4	-1.8	1.6	19.8	1.8	17.8	1.6	21.9	-31.1	19.5	-19.4	-14.5	-17.6
42	-0.9	2.2	-0.3	-0.6	1.2	2.5	4.9	2.2	0.2	7.4	0.2	4.2	0.7	-0.5	4.4	-21.3	6.7	-27.6	8.8	-16.0
43	2.0	2.5	0.0	2.0	4.5	-3.3	3.8	-2.3	-1.0	0.4	3.6	4.9	0.0	3.6	8.7	-27.1	18.3	0.0	-27.1	-13.7
All universities	0.6	4.0	0.5	0.1	4.6	-0.2	4.0	0.0	-0.2	3.8	5.7	3.6	4.8	0.9	9.5	-0.8	2.6	-0.3	-0.5	1.8